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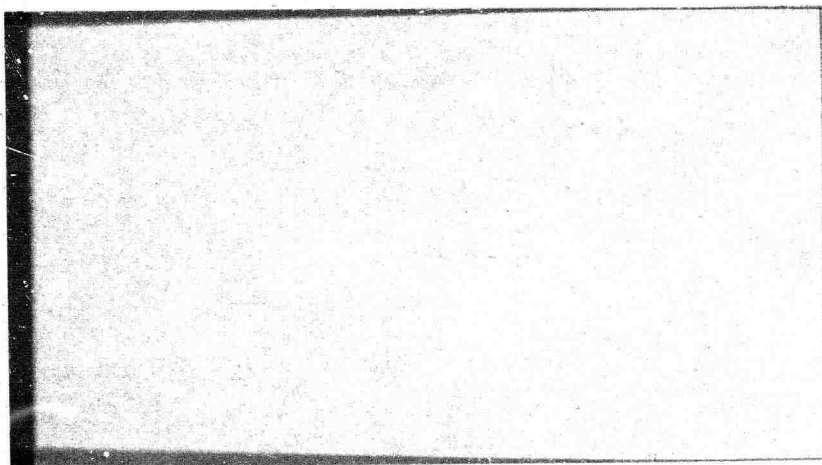
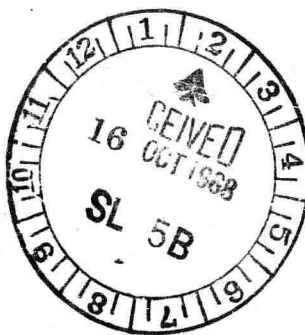
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AUTHORITY

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FINAL REPORT

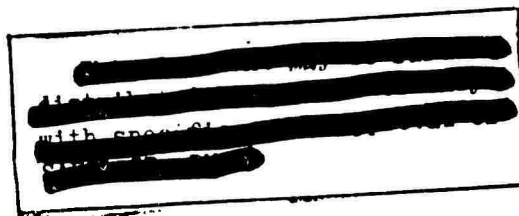
GEMINI B BLAST SHIELD:

MECHANICAL PORPERTIES OF ALUMINUM FLEXCORE

Report 058-AKA.04 Model 195B

Contract No. F04695-67-C-0023

Laboratories: Materials



**MCDONNELL COMPANY**  
LAMBERT-ST LOUIS MUNICIPAL AIRPORT  
BOX 516, ST LOUIS, MO 63166

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## ABSTRACT

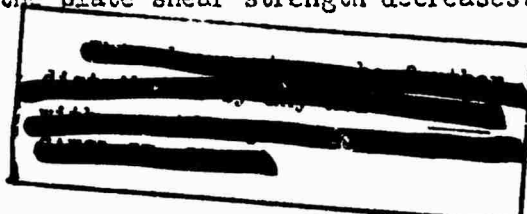
The object of this test was to determine the plate shear strength and the flatwise bare compressive strength of aluminum flexcore ~~manufactured by Hexcel Incorporated of Arlington, Texas. In addition,~~ <sup>as well as</sup> the effect of the Flexcore thickness on the plate shear strength ~~was determined.~~

The Gemini B Blast shield is a sandwich construction composed of glass fabric reinforced plastic skins adhesively bonded to aluminum Flexcore. The results of this test will provide mechanical property data for the design of the blast shield.

This test revealed that the Flexcore (4.1 lbs/ft<sup>3</sup> density) fabricated from 5052 aluminum alloy had an average plate shear strength of 291 psi in the "L" direction and 171 psi in the "W" direction. The 5052 Flexcore (7.1 lbs/ft<sup>3</sup> density) had an average shear strength of 614 psi in the "L" direction and 373 psi in the "W" direction. These average values were obtained from specimens .625 inches thick. The Flexcore (4.1 lbs/ft<sup>3</sup>) fabricated from 5056 aluminum alloy exhibited an average plate shear strength of 349 psi in the "L" direction and 203 psi in the "W" direction. These average values were obtained from specimens 1.100 inches thick.

The compression test data shows the Flexcore fabricated from 5052 alloy in 4.1 and 7.1 lbs/ft<sup>3</sup> had an average compressive strength of 525 and 1437 psi, respectively. The Flexcore fabricated from 5056 aluminum alloy and with a density of 4.1 lbs/ft<sup>3</sup> had a compressive strength of 735 psi.

The plate shear strength vs Flexcore thickness data indicates that as the thickness of the core increases the plate shear strength decreases.



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## 1. INTRODUCTION

This test was conducted to determine the plate shear strength and the flat-wise compressive strength of aluminum Flexcore manufactured by Hexcel, Incorporated of Arlington, Texas. In addition, the effect of the Flexcore thickness on the plate shear strength was determined.

The Gemini B Blast Shield is a sandwich construction composed of glass fabric reinforced plastic skins adhesively bonded to aluminum Flexcore. This test will provide mechanical property data for the design of the blast shield.

This test was conducted by the McDonnell Company Metallurgical Laboratory during the period 25 January through 3 June 1968.

## 2. TEST MATERIAL

The test material utilized during this investigation was aluminum Flexcore obtained from Hexcel, Incorporated, Arlington, Texas, and consisted of the following items:

- (a) Aluminum Flexcore, 9 square feet, Al/F-40-5052, 0.0025 inch 4.1 lbs/ft<sup>3</sup> 0.625 inches thick, comprising 3.0 square feet from each of three blocks.
- (b) Aluminum Flexcore, 9 square feet, Al/F-40-5052, 0.0047 inch 7.1 lbs/ft<sup>3</sup>, 0.625 inches thick, comprising 3.0 square feet from each of three blocks.
- (c) Aluminum Flexcore, 9 square feet, Al/F-40-5056, 0.0025 inch 4.1 lbs/ft<sup>3</sup>, 1.100 inches thick, comprising 3.0 square feet from each of three blocks.
- (d) Aluminum Flexcore, 1 square foot each, 0.250, 0.500, 0.750, 1.000, 1.450, 2.000, and 2.500 inches thick from one of the blocks used to supply material for item (a).

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## 3. TEST PROCEDURE

A total of 160 plate shear specimens were cut from the Flexcore to the dimensions shown in Table 1 on page 9 . Five specimens were cut with the length parallel to the ribbon direction ("L" direction) and five were cut with the length perpendicular to the ribbon direction ("W" direction) from each of the groups listed in Table 1 on page 9 . After cutting, the specimens were bonded to steel shear plates as shown in Figure 1 on page 5 . The core was bonded to the plates, using HT-424 adhesive cured for 2 hours at  $335 \pm 10^{\circ}\text{F}$ .

The ultimate strength of the bonded specimens was determined at room temperature in the 30,000 pound universal testing machine by loading them to failure at a machine head travel rate of .015 inches/minute. A photograph of the test setup is presented in Figure 2 on page 6 . The ultimate shear stress is obtained by dividing the ultimate load by the flatwise area of the specimen.

A total of 45 flatwise compression specimens were cut from the Flexcore to the dimensions shown in Table 2 on page 9 . Five specimens were cut from each of the nine groups.

The ultimate compressive strength of the specimens was determined at room temperature in the 30,000 pound universal testing machine by loading them to failure at a machine head travel rate of .003 inches/minute/inch of core height. A photograph of the test setup is presented in Figure 3 on page 7 . The ultimate compressive stress is obtained by dividing the ultimate load by the flatwise area of the specimen.

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## 4. TEST RESULTS

The results of the plate shear tests conducted during this investigation are presented in Tables 3 through 8 on pages 10 through 13. Results of the compression tests are shown in Tables 9 and 10 on pages 16 and 17. The plate shear strength vs core thickness data accumulated during this test is presented graphically in Figure 4 on page 8.

## 5. SUMMARY OF RESULTS

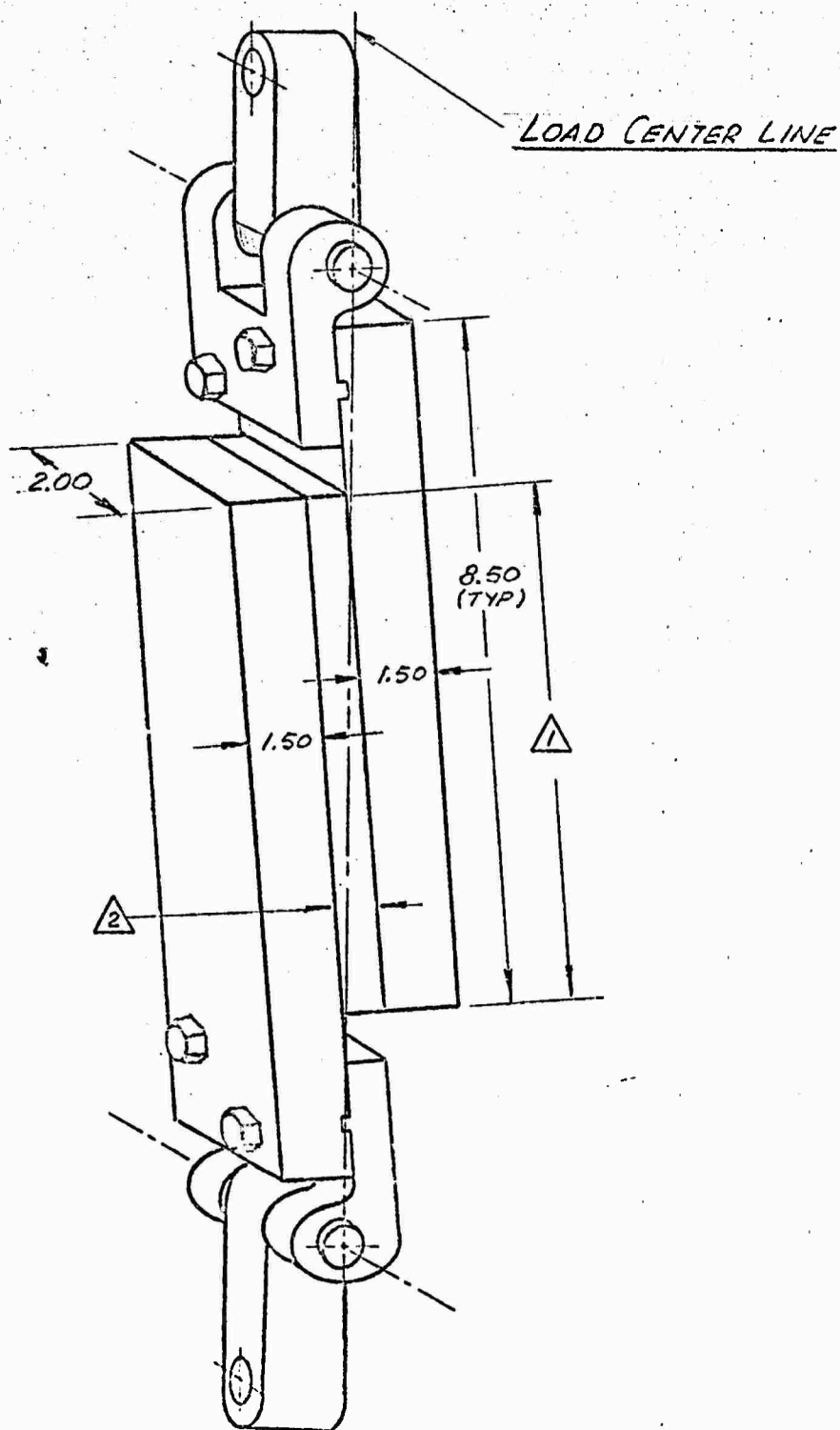
This test revealed that the Flexcore (4.1 lbs/ft<sup>3</sup> density) fabricated from 5052 aluminum alloy had an average plate shear strength of 291 psi in the "L" direction and 171 psi in the "W" direction. The 5052 Flexcore (7.1 lbs/ft<sup>3</sup> density) had an average shear strength of 614 psi in the "L" direction and 378 psi in the "W" direction. These average values were obtained from specimens .625 inches thick. The Flexcore (4.1 lbs/ft<sup>3</sup>) fabricated from 5056 aluminum alloy exhibited an average plate shear strength of 349 psi in the "L" direction and 203 psi in the "W" direction. These average values were obtained from specimens 1.100 inches thick.

The compression test data shows the Flexcore fabricated from 5052 alloy in 4.1 and 7.1 lbs/ft<sup>3</sup> had an average compressive strength of 525 and 1437 psi, respectively. The Flexcore fabricated from 5056 aluminum alloy and with a density of 4.1 lbs/ft<sup>3</sup> had a compressive strength of 735 psi.

The plate shear strength vs Flexcore thickness data indicates that as the thickness of the core increases the plate shear strength decreases.

FIGURE 1

SKETCH OF PLATE SHEAR TEST SETUP



1 DIMENSION DETERMINED BY SPECIMEN LENGTH.

2 DIMENSION DETERMINED BY SPECIMEN THICKNESS.

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PLATE SHEAR TEST SETUP

FIGURE 2



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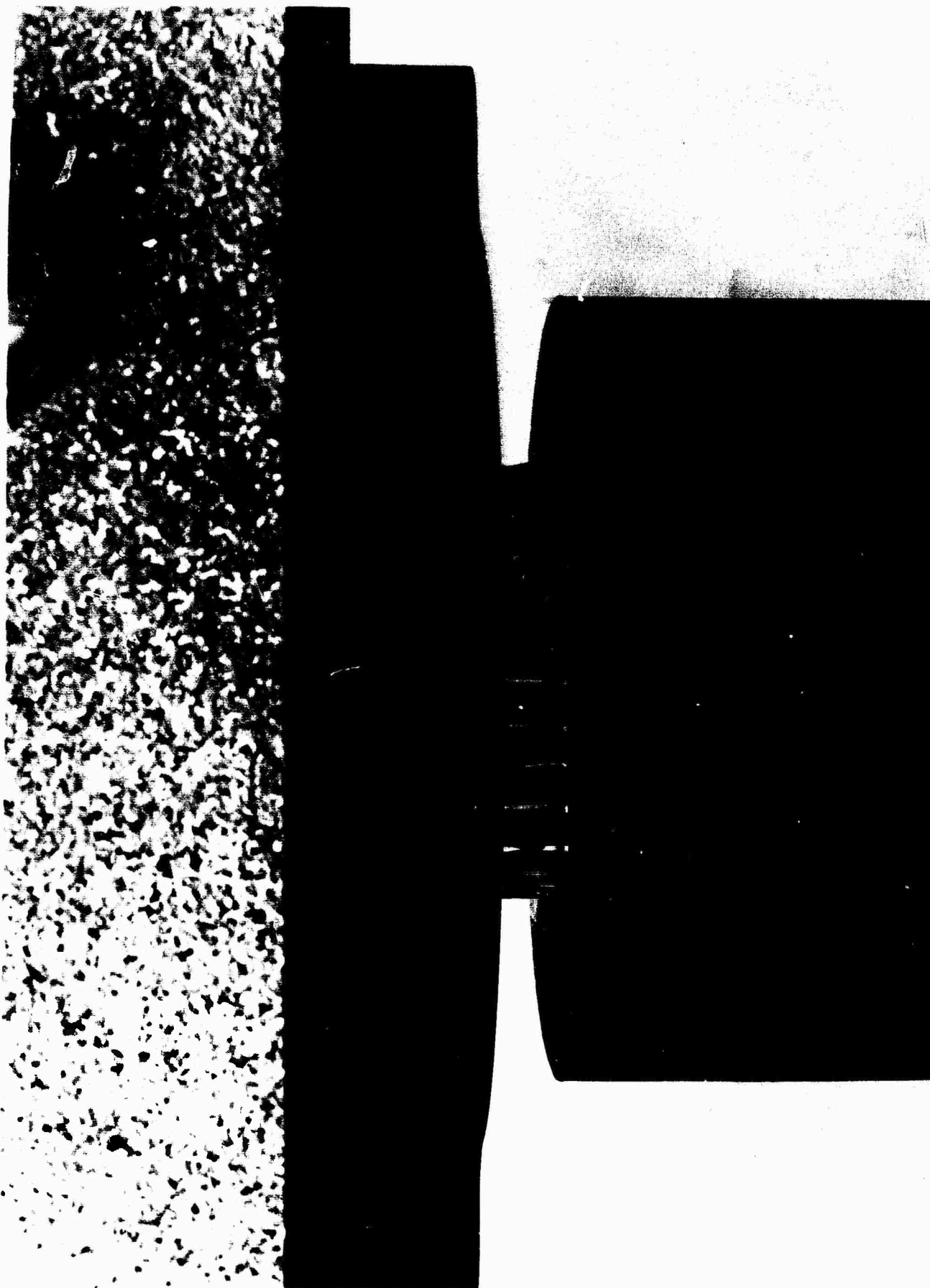
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FLATWISE COMPRESSION TEST SETUP

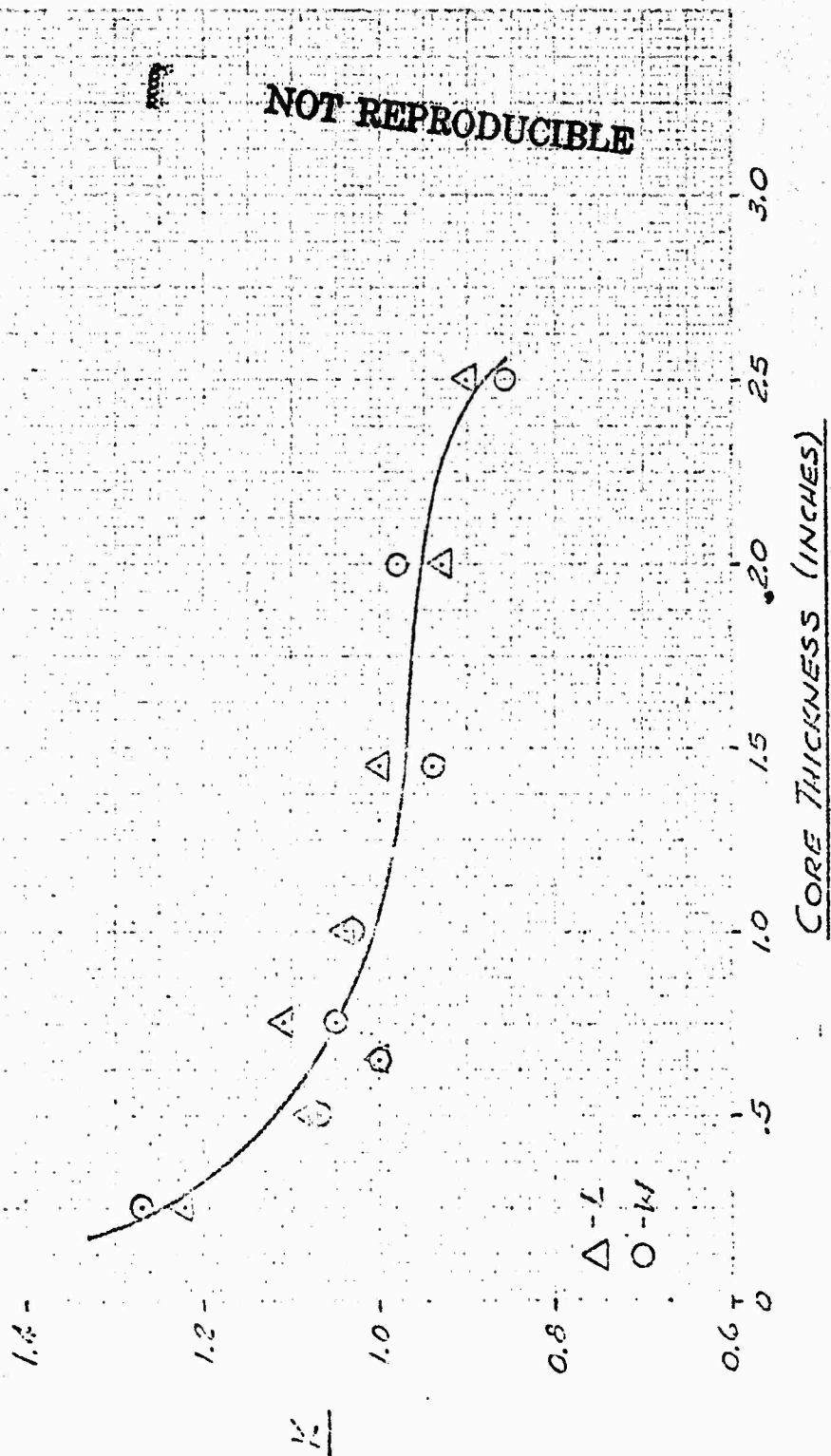
FIGURE 3



**FIGURE 4**

CORE THICKNESS VS PLATE SHEAR STRENGTH

$K = \frac{\text{PLATE SHEAR STRENGTH FOR GIVEN CORE THICKNESS}}{\text{PLATE SHEAR STRENGTH FOR 0.625" CORE THICKNESS}}$



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## PLATE SHEAR SPECIMENS

TABLE 1

GROUP NUMBER	BLOCK NUMBER	FLEXCORE IDENTIFICATION	SPECIMEN SIZE (INCHES)
1	2362	A1/F-40-5052-0.0025 in.	6.125 x 2.00 x .625
2	2363	4.1 lb/ft <sup>3</sup>	↓ ↓ ↓
3	2364	↓	↓ ↓ ↓
4	2294	A1/F-40-5052-0.0047 in.	↓ ↓ ↓
5	2298	7.1 lb/ft <sup>3</sup>	↓ ↓ ↓
6	2300	↓	↓ ↓ ↓
7	2362	A1/F-40-5052-0.0025 in.	4.50 x 2.00 x .250
8	↓	4.1 lb/ft <sup>3</sup>	6.00 x 2.00 x .500
9	↓	↓	6.25 x 2.00 x .750
10	↓	↓	6.50 x 2.00 x 1.000
11	↓	↓	6.50 x 2.00 x 1.450
12	↓	↓	6.50 x 2.00 x 2.000
13	↓	↓	6.50 x 2.00 x 2.50
14	2521	A1/-40-5056-0.0025 in.	6.125 x 2.00 x 1.100
15	2526	4.1 lb/ft <sup>3</sup>	↓ ↓ ↓
16	2538	↓	↓ ↓ ↓

## COMPRESSION SPECIMENS

TABLE 2

GROUP NUMBER	BLOCK NUMBER	FLEXCORE IDENTIFICATION	SPECIMEN SIZE (INCHES)
1	2362	A1/F-40-5052-0.0025 in.	3.00 x 3.00 x .625
2	2363	4.1 lb/ft <sup>3</sup>	↓ ↓ ↓
3	2364	↓	↓ ↓ ↓
4	2294	A1/F-40-5052-0.0025 in.	↓ ↓ ↓
5	2298	7.1 lb/ft <sup>3</sup>	↓ ↓ ↓
6	2300	↓	↓ ↓ ↓
14	2521	A1/F-40-5056-0.0025 in.	3.00 x 3.00 x 1.100
15	2526	4.1 lb/ft <sup>3</sup>	↓ ↓ ↓
16	2538	↓	↓ ↓ ↓

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## PLATE SHEAR TEST RESULTS

### TABLE 3

SPECIMEN NUMBER *	FLEXCORE IDENTIFICATION	ULTIMATE LOAD (LBS)	ULTIMATE SHEAR STRENGTH (PSI)	AVG. ULTIMATE SHEAR STRENGTH (PSI)
1L 2L 3L 4L 5L	A1/F-40-5052-0.0025 in. 4.1 lb/ft <sup>3</sup>  Group No. 1 Block No. 2362 .625 inches thick	3245	265	273
		3375	276	
		3535	289	
		3290	269	
		3255	266	
1W 2W 3W 4W 5W		2200	180	174
		2060	168	
		2115	173	
		2120	173	
		2170	177	
1L 2L 3L 4L 5L	A1/F-40-5052-0.0025 in. 4.1 lb/ft <sup>3</sup>  Group No. 2 Block No. 2363 .625 inches thick	3495	285	287
		3590	293	
		3570	291	
		3410	278	
		3510	287	
1W 2W 3W 4W 5W		2110	173	173
		2070	169	
		2130	174	
		2140	175	
		2125	174	
1L 2L 3L 4L 5L	A1/F-40-5052-0.0025 in. 4.1 lb/ft <sup>3</sup>  Group No. 3 Block No. 2364 .625 inches thick	3665	299	314
		3670	300	
		3835	313	
		3880	317	
		4200	343	
1W 2W 3W 4W 5W		2085	170	167
		1975	161	
		2060	168	
		2070	169	
		2025	165	

\*"L" indicates the ribbon direction is parallel to the loading direction  
and "W" indicates the ribbon direction is perpendicular to the loading direction.

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## PLATE SHEAR TEST RESULTS

TABLE 4

SPECIMEN NUMBER	FLEXCORE IDENTIFICATION	ULTIMATE LOAD (LBS)	ULTIMATE SHEAR STRENGTH (PSI)	AVG. ULTIMATE SHEAR STRENGTH (PSI)
1L	Al/F-40-5052-0.0047 in. 7.1 lb/ft <sup>3</sup>  Group No. 4 Block No. 2294 .625 inches thick	7225	590	602
2L		7300	596	
3L		7075	578	
4L		7525	614	
5L		7725	631	
1W		4625	378	374
2W		4575	374	
3W		4595	375	
4W		4570	373	
5W		4535	370	
1L	Al/F-40-5052-0.0047 in. 7.1 lb/ft <sup>3</sup>  Group No. 5 Block No. 2298 .625 inches thick	7525	614	611
2L		7300	596	
3L		7475	610	
4L		7625	622	
5L		7450	608	
1W		4750	388	387
2W		4745	387	
3W		4720	385	
4W		4830	394	
5W		4675	382	
1L	Al/F-40-5052-0.0047 in. 7.1 lb/ft <sup>3</sup>  Group No. 6 Block No. 2300 .625 inches thick	8500	694	628
2L		7575	618	
3L		7575	618	
4L		7375	602	
5L		7425	606	
1W		4605	376	374
2W		4785	391	
3W		4480	366	
4W		4605	376	
5W		4455	364	

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PLATE SHEAR TEST RESULTS

TABLE 5

SPECIMEN NUMBER	FLEXCORE IDENTIFICATION	ULTIMATE LOAD (LBS)	ULTIMATE SHEAR STRENGTH (PSI)	AVG. ULTIMATE SHEAR STRENGTH (PSI)
1L	Al/F-40-5056-0.0025 in. 4.1 lb/ft <sup>3</sup>  Group 14 Lot No. 2521 .625 inches thick	4415	340	341
2L		4435	341	
3L		4485	345	
4L		4335	334	
5L		4515	347	
1W		2605	200	202
2W		2610	201	
3W		2560	197	
4W		2660	205	
5W		2680	206	
1L	Al/F-40-5056-0.0025 in. 4.1 lb/ft <sup>3</sup>  Group 15 Lot No. 2526 .625 inches thick	4710	362	365
2L		4715	363	
3L		4740	365	
4L		4700	361	
5L		4890	376	
1W		2735	210	211
2W		2720	209	
3W		2725	210	
4W		2760	212	
5W		2760	212	
1L	Al/F-40-5056-0.0025 in. 4.1 lb/ft <sup>3</sup>  Group 16 Lot No. 2538 .625 inches thick	4055	312	342
2L		4735	364	
3L		4055	312	
4L		4450	342	
5L		4915	378	
1W		2540	195	195
2W		2510	193	
3W		2540	195	
4W		2590	199	
5W		2510	193	

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## PLATE SHEAR TEST RESULTS

## TABLE 6

SPECIMEN NUMBER	FLEXCORE IDENTIFICATION	ULTIMATE LOAD (LBS)	ULTIMATE SHEAR STRENGTH (PSI)	AVG. ULTIMATE SHEAR STRENGTH (PSI)
1L	A1/F-40-5052-0.0025 in. 4.1 lb/ft <sup>3</sup>  Group No. 7 Block No. 2362	2935	326	333
2L		2945	327	
3L		2965	329	
4L		2980	331	
5L		3150	350	
1W	.250 inches thick	2060	229	221
2W		1905	211	
3W		1885	209	
4W		2050	228	
5W		2045	227	
1L	A1/F-40-5052-0.0025 in. 4.1 lb/ft <sup>3</sup>  Group No. 8 Block No. 2362	3395	283	294
2L		3540	295	
3L		3430	285	
4L		3655	305	
5L		3625	302	
1W	.500 inches thick	2310	193	187
2W		2200	183	
3W		2210	184	
4W		2230	186	
5W		2295	191	
1L	A1/F-40-5052-0.0025 in. 4.1 lb/ft <sup>3</sup>  Group No. 9 Block No. 2362	3855	308	302
2L		3910	313	
3L		3760	301	
4L		3675	294	
5L		3645	292	
1W	.750 inches thick	2350	188	182
2W		2260	181	
3W		2255	180	
4W		2245	180	
5W		2270	182	

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## PLATE SHEAR TEST RESULTS

TABLE 7

SPECIMEN NUMBER	FLEXCORE IDENTIFICATION	ULTIMATE LOAD (LBS)	ULTIMATE SHEAR STRENGTH (PSI)	AVG. ULTIMATE SHEAR STRENGTH (PSI)
1L	Al/F-40-5052-0.0025 in. 4.1 lb/ft <sup>3</sup>  Group No. 10 Block No. 2362	3825	294	286
2L		3350	258	
3L		3545	273	
4L		4000	308	
5L		3840	295	
1W	1.000 inches thick	2320	179	179
2W		2230	171	
3W		2435	187	
4W		2310	178	
5W		2320	179	
1L	Al/F-40-5052-0.0025 in. 4.1 lb/ft <sup>3</sup>  Group No. 11 Block No. 2362	3545	273	273
2L		3530	272	
3L		3525	271	
4L		3740	288	
5L		3380	260	
1W	1.450 inches thick	2170	167	164
2W		2100	162	
3W		2130	164	
4W		2155	166	
5W		2100	162	
1L	Al/F-40-5052-0.0025 in. 4.1 lb/ft <sup>3</sup>  Group No. 12 Block No. 2362	3185	245	253
2L		3295	253	
3L		3380	260	
4L		3215	247	
5L		3350	258	
1W	2.000 inches thick	2180	168	170
2W		2255	174	
3W		2250	173	
4W		2035	157	
5W		2285	176	

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TABLE 8

PLATE SHEAR TEST RESULTS

SPECIMEN NUMBER	FLEXCORE IDENTIFICATION	ULTIMATE LOAD (LBS)	ULTIMATE SHEAR STRENGTH (PSI)	AVG. ULTIMATE SHEAR STRENGTH (PSI)
1L	AL/F-40-5052-0.0025 in. 4.1 lb/ft <sup>3</sup>  Group No. 13 Block No. 2362	3200	246	246
2L		3400	262	
3L		3110	239	
4L		2840	218	
5L		3420	263	
1W	2.500 inches thick	2105	162	149
2W		1970	152	
3W		1735	134	
4W		1990	153	
5W		1870	144	

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## FLEXCORE FLATWISE COMPRESSIVE DATA

TABLE 9

SPECIMEN NUMBER	FLEXCORE IDENTIFICATION	ULTIMATE LOAD (PSI)	ULTIMATE COMPRESSIVE STRENGTH (PSI)	AVG. ULTIMATE COMPRESSIVE STRENGTH (PSI)
1	A1/F-40-5052-0.0025 in.	4375	486	496
2	4.1 lb/ft <sup>3</sup>	4665	518	
3	Group No. 1	4440	493	
4	Block No. 2362	4395	488	
5	.625 inches thick	4465	496	
1	A1/F-40-5052-0.0025 in.	4685	521	528
2	4.1 lb/ft <sup>3</sup>	4965	552	
3	Group No. 2	4855	539	
4	Block No. 2363	4570	508	
5	.625 inches thick	4665	518	
1	A1/F-40-5052-0.0025 in.	4840	538	552
2	4.1 lb/ft <sup>3</sup>	4595	511	
3	Group No. 3	4800	533	
4	Block No. 2364	5380	598	
5	.625 inches thick	5200	578	
1	A1/F-40-5052-0.0025 in.	12,825	1425	1514
2	7.1 lb/ft	13,275	1475	
3	Group No. 4	13,800	1533	
4	Block No. 2294	13,900	1544	
5	.625 inches thick	14,350	1594	
1	A1/F-40-5052-0.0047 in.	13,275	1475	1430
2	7.1 lb/ft <sup>3</sup>	13,100	1456	
3	Group No. 5	12,825	1425	
4	Block No. 2298	12,950	1439	
5	.625 inches thick	12,175	1353	
1	A1/F-40-5052-0.0047 in.	12,800	1422	1366
2	7.1 lb/ft <sup>3</sup>	13,150	1461	
3	Group No. 6	11,776	1308	
4	Block No. 2300	11,700	1300	
5	.625 inches thick	12,050	1339	

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TABLE 10

FLEXCORE FLATWISE COMPRESSIVE DATA

SPECIMEN NUMBER	FLEXCORE IDENTIFICATION	ULTIMATE LOAD (LBS)	ULTIMATE COMPRESSIVE STRENGTH (PSI)	AVG. ULTIMATE COMPRESSIVE STRENGTH (PSI)
1	A1/F-40-5055-0.0025 in.	6550	728	713
2	4.1 lb/ft <sup>3</sup>	6375	708	
3	Group No. 14	6700	744	
4	Block No. 2521	6425	714	
5	1.100 inches thick	6050	672	
1	A1/F-40-5056-0.0025 in.	7400	822	821
2	4.1 lb/ft <sup>3</sup>	7150	794	
3	Group No. 15	7600	844	
4	Block No. 2526	7650	850	
5	1.100 inches thick	7175	797	
1	A1/F-40-5056-0.0025 in.	6150	683	672
2	4.1 lb/ft <sup>3</sup>	5725	636	
3	Group No. 16	5950	661	
4	Block No. 2538	6650	739	
5	1.100 inches thick	5775	642	